Project Partners:

- Schneider Electric
- ABB
- APS
- ARM
- Boliden
- Prodatec
- IFAK
- Jaguar
- SAP
- Siemens
- Tampere University of Technology
- Loughborough University
- Polish University of Technology
- Technical University of Dresden

**Sixth Framework Programme**

**Information Society Technologies**

**Embedded Systems**

**INTEGRATED PROJECT 2006 - 2009**

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1,100 person months

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**Duration:**

36 months

**Visit our website:** WWW.SOCRADIES.EU
**INTRODUCTION TO SOCRADES**

SOCRADES is a European research and advanced development project, part of the Information Society Technologies (IST) initiative of the European Union’s 6th Framework Programme.

Since manufacturing plays a vital role in economy and society, remaining fundamental to creating stable employment, the adoption of manufacturing innovations is needed in order to promote performance improvement of European manufacturing processes.

In this context, the primary objective of the SOCRADES project is to develop a design, execution and management platform for next-generation industrial automation systems, exploiting the Service Oriented Architecture paradigm both at the device and at the application level.

**Autonomous Smart-Devices in an Evolving Context**

The increasing availability of affordable, high-performance, low-power electronic components and the emerging Internet / Ethernet (wired or wireless) technologies as the basic carriers for interconnecting electronic devices are at the basis of the possibilities of improving communication and integration of heterogeneous devices, with particular emphasis on platform independence, real-time requirements, robustness and security.

These technologies can be leveraged to build advanced functionality into embedded devices, thus enabling new distributed application paradigms based on interconnected “smart devices” with a high level of autonomy.

This applies to several types of embedded devices, used in industrial automation systems, automotive electronics, telecommunications equipment, building controls, home automation, telemetry, medical instrumentation, and many others.

The SOCRADES project will operate in this sense of general applicability across a broad range of application domains, while using as its application cornerstone one of the most prominent embedded systems domains, viz. manufacturing and process automation.

**Four Technology Areas**

The SOCRADES integrated project will create new methodologies, technologies and tools for the modelling, design, implementation and operation of networked systems made up of smart embedded devices, focusing on four main Technology Areas:

1. **Ad-hoc networking service platform — Service-oriented Architectures (SOA)**, as a set of architectural tenets for building autonomous yet interoperable systems.

2. **Wireless sensor/actuator networking infrastructure**: focusing on monitoring and human machine interface applications.

3. **Enterprise Integration**, focusing on the link between application-level and device-level functionality through a common, unifying technological approach, based on the service-oriented architecture (SOA) paradigm.

4. **System engineering & management**, not only to automatically generate control logic software but also to allow the support of distributed control system configurations and of multiple aspects of the complete systems engineering life cycle.

**The “Collaborative Automation” Paradigm**

The SOCRADES project adopts the “collaborative automation” paradigm: the aim is to effectively develop tools and methods, to achieve flexible, re-configurable, scalable, interoperable network-enabled collaboration between decentralised and distributed embedded systems.

The SOCRADES technical approach is to create a service-oriented ecosystem: networked systems are composed by smart embedded devices interacting with both physical and organizational environment, pursuing well-defined system goals. Taking the granularity of intelligence to the device level allows intelligent system behaviour to be obtained by composing configurations of devices that introduce incremental fractions of the required intelligence. This approach favours adaptability and rapid reconfigurability, as re-programming of large monolithic systems is replaced by reconfiguring loosely coupled embedded units.

From a functional perspective, the focus is on managing the vastly increased number of intelligent devices and mastering the associated complexity.

From a run-time infrastructure viewpoint, the focus will be on a new breed of very flexible real-time embedded devices (wired/wireless) that are fault-tolerant, reconfigurable, safe and secure. Auto-configuration management is a new challenge that will be addressed through basic plug-and-play and plug-and-run mechanisms.

The use of device-level Service Oriented Architecture, will contribute to the creation of an open, flexible and agile environment, by extending the scope of the collaborative architecture approach through the application of a unique communications infrastructure, down from the lowest levels of the device hierarchy up into the manufacturing enterprise’s higher-level business process management systems.
AD-HOC NETWORKING SERVICES PLATFORM
Service-Oriented Architectures

A key goal of SOCRADeS is to specify a service-oriented framework for device-level infrastructures, where system intelligence is implemented by intelligent physical agents embedded in smart devices.

The umbrella paradigm underpinning novel collaborative system design is to consider the set of intelligent system units as a conglomerate of distributed, autonomous, intelligent, pro-active, fault-tolerant and reusable units, which operate as a set of cooperating entities. These entities are capable of working in a pro-active manner, initiating collaborative actions and dynamically interacting with each other in order to achieve both local and global objectives, down from the physical device control level up to the higher levels of the business process management system.

Why is this Technology Area important for Manufacturing in the Future?

Reconfigurability: the adoption of SOA and an ad-hoc services platform facilitates the discovery and composition of applications by re-configuration rather than reprogramming. There is no need for software re-programming of large monolithic systems but rather a reconfiguration of loosely coupled embedded units.

Interoperability: service-oriented architecture (SOA) paradigm, using opaque interface and loose coupling concept on widely heterogeneous devices, facilitates either the discovery and composition of complex services that can use devices deployed in various platforms and networking technologies (even interoperating with devices of partners’ enterprises).

Vertical integration: SOA paradigm implemented through Web Services technologies, at the ad hoc device network level enables the adoption of a unifying technology for all levels of the enterprise, from sensors and actuators to enterprise business processes. SOA thus represents an effective support in order to reach seamless integration with the enterprise systems.

Scalability: this important requirement, especially in manufacturing, can be spontaneously supported by SOA and by an ad-hoc services platform. The identification of a new device can be done opaquely through SOA, without needing to deeply modify the overall system.

Diagnosability: the technology behind SOA and the enhancement that SOCRADeS is generating will support both the discovery/identification of failures (sensors, resources, controller, etc.) and their repair in a real-time and seamless fashion.

Reusability: SOA improves reusability of resources/devices, that are encapsulated in services. Since every component can be easily recognized and managed by any SOA-enabled system, this increases its reusability, even into another system. This involves both cost reduction and sustainability enhancement.

Intellectual Protection: with SOCRADeS, SOA-enabled, architecture a more effective Intellectual Protection will be available, since the architecture itself is based on exposing services not the technology behind them. SOA will automatically hide how the service is furnished, showing only the functionality of the service itself.

Action List for this Goal:

- Specify and implement an enhanced version of the device-level SOA infrastructure – based on the Devices Profile for Web Services (DPWS) – for encapsulating intelligence and sensing/actuating skills as services, as well as to specify associated frameworks for management and orchestration of device-level services.
- Define a methodology for describing services with semantic mark-up that can be interpreted and processed by agents (Semantic Web Services), for the discovery, selection and composition of resources.
- Specify a framework for service-enabled intelligent physical agents
WIRELESS SENSOR/ACTUATOR NETWORKING INFRASTRUCTURE

One of the main objectives of the project is to specify new wireless communication protocols that provide the required reliability, safety, security and real-time parameters for embedded devices.

“A sensor/actuator network is a network of equal participants without any central control, in which sensors and actuators directly interact with each other with the objective to commonly solve day-to-day automation tasks.”

Although, in theory, these are not imperative for sensor/actuator networks, wired sensor/actuator networks would be of no practical relevance as the wiring of a high amount of sensor and actuator nodes would be difficult and not economic. In confirmation of this evidence, the domain of industrial communication shows the trend of adopting wireless technologies for networked embedded automation devices.

Why is this Technology Area important for manufacturing in the future?

Reconfigurability: wireless technologies can significantly facilitate deployment and reconfiguration by eliminating the need for installing and maintaining cabling, reducing both costs and time. However till now the industrial need for enhancing reliability and real-time performance in wireless technology has been an issue.

Mobility: the adoption of WSAN will strongly support moving equipment, e.g., robots. In fact any even complex composition of sensors/actuators (i.e.: robot) is supposed to be managed and recognised by the overall infrastructure.

Maintainability: the WSAN, providing a set of agile and economic sensors/actuators will definitely enables greater opportunities for supporting maintenance and fault tolerance. In fact the presence of a large number of low-cost sensors/actuators will increase the granularity of the information that can be available for the overall (maintenance) system.

Cost efficiency: the elimination of the need for installing and maintaining cabling, will reduce costs in general terms. This includes material costs (e.g.: buying cost and maintenance cost), time-related costs (e.g.: opportunity cost during installation, movement or elimination of resources), labour costs (e.g.: cost for installing, maintaining).

Interoperability: the elimination of cable connectors strongly facilitates an improved seamless interoperation. The utilization of widely heterogeneous systems is definitely allowed by adopting a common wireless architecture.

New Applications: with the adoption of WSAN, new business applications can become feasible due to the elimination of cabling (e.g.: monitoring, controlling within difficult environments through agile wireless sensors/actuators).

Within this Technology Area some design issues are still not well solved in the state of art; however they are critical to obtain an efficient, reliable, safe and secure infrastructure and so are deeply addressed by SOCRADES. The following list contains some examples of current issues in WSANs, depending on the actual application: type of service, fault tolerance, limited energy supply, small computational resources, autonomy, multi-functionality, quality of service, low priced.

Action List for this Goal:

• Specification of middleware that encapsulates the different mechanisms to offer specific QoS provisions and the different underlying wireless technologies.
• Research on node architecture, sensor integration and the interface between sensors and the network
• Study of Wireless Network topology, self-configuration, self-management, routing, scalability
• Development of Communication technologies for WSN in industrial environment
• Research on power supply for the network infrastructure as well as the sensor itself
• Development of New Services with Wireless Sensor Networks
• Merging of the DPWS application models with the latest architectures used in wireless technologies
A fundamental goal of SOCRADES is to enable the integration of device-level services with enterprise systems.

The application of the SOA paradigm and Web Services technology, as proposed in SOCRADES, results in a single unifying application-level communications technology across the enterprise. Hence a main relevant topic is the integration of aggregated device-level services with higher-level Web Services and business processes situated at the level of business applications - in particular Enterprise Resource Planning (ERP) systems - in order to demonstrate seamless integration of device level functionality into higher-order business application scenarios in manufacturing, logistics, or similar areas. The integration should not require changes to business application code, but be based on and leverage the Web Service-enablement of device networks as addressed by SOCRADES.

Why is this Technology Area important for manufacturing in the future?

Several business scenarios can be used to show the relevance of Enterprise Integration; SOCRADES selected the following scenarios to demonstrate how integration can lead to better business infrastructure.

Business Activity Monitoring: the increased granularity that can be seen from the enterprise system through the implementation of an effective seamless integration allow low level information being available for real-time measure of key performance indicators and for real-time reaction to relevant events and exceptions with minimised latency.

Mobile Equipment Assistance: it refers to the process of using mobile devices as a mean to realise part of a business process or even as the end-devices to be monitored. The aim is to loosely couple the back-end systems (enterprise infrastructure) with the front-end ones (machines and devices available to the workforce on-site), but still be able to realise the whole business process in a flexible and dynamic way. A series of services can be realised such as remote diagnostics, predictive maintenance, etc.

Maintenance Optimisation: this industrial relevant issue will be strongly supported by low level information being available “on demand” to the high level business application (e.g.: by integrating device-level services and diagnostics with business applications in maintenance and asset management, actual device diagnostics data can be compared to stored device profiles in order to detect situations requiring maintenance).

Overall Equipment Effectiveness: the seamless integration of the manufacturing devices level into the business applications level is a basis for capturing information about equipment usage. With the adoption of this information a better utilization of assets (people, equipment, and materials) through a comprehensive view of overall equipment efficiency can be allowed.

Customized manufacturing with late order freeze: by connecting the shop floor with the business system, the period during which the customer can change a product parameter can be stretched to the point, where the parameter is actually incorporated in the product (order penetration point). Additionally, the customer can be informed about the production stage and the expected completion of the order in near real-time.

**Action List for this goal:**

- Definition of new integration concepts taking into account the emerging requirements of business applications and the explosion of available information from the device level.
- Consideration towards the availability of real-time event information, which will be used to specify new enterprise integration approaches for applications such as business activity monitoring, overall equipment effectiveness optimisation, maintenance optimisation, etc.
System Engineering & Management

Within this area, the main goal of SOCRADES is to specify systematic approaches and engineering tools that will facilitate the engineering of the overall system behaviour.

The goal is to combine support for the configuration and optimisation of networked control capabilities with device management, configuration and lifecycle support services. End-users are needed to assist in exploring these new directions.

Why is this Technology Area important for Manufacturing in the future?

Reconfigurability: a tool able to support application design, simulation and monitoring of real-time intelligent embedded components will be necessary within the complex and changeable context in which reconfigurability will be required.

Complexity management: the explosion in number of embedded devices will require new tools and methods for managing a new degree of complexity.

Cost efficiency: an efficient and standardized tool that supports the overall system engineering and management will reduce general costs due to the time saved in designing the model.

Reactivity: the system engineering and management addressed by SOCRADES will contribute to enhance the reactivity of the overall enterprise, by supporting it with a more rapid and efficient tool for designing and validating systems.

Integration: with the adoption of system engineering and management tools the integration either within the enterprise and between enterprise partners will be supported. SOA is the enabling technology for integration; however a tool that provides system modelling is necessary.

It is necessary to support application design, simulation and monitoring of real-time intelligent embedded components. Simultaneously, it is necessary to support the integration of intelligent embedded devices with higher-level business process systems (enterprise dimension), with supply chain partners (value/supply-chain dimension) and within a lifecycle engineering context (lifecycle dimension).

An engineering environment should be created for the lifecycle support of distributed embedded devices in both wired and wired automation systems. In SOCRADES, this engineering system will be specified to meet the user applications requirements for the domains covered by the project.

This goal will require:

- The creation of an effective tool-set whose benefit and value are clear within the user’s business context
- Focus also on the borderline between engineering and run-time. In agile and mobile embedded systems, this borderline blurs, (i.e.: the run-time system and the engineering system are mutually related parts of a single system).
- The semantic level of configuration to be supported by the engineering platform
SOCRADES
OBJECTIVES AND EXPECTED RESULTS

A key goal of SOCRADES is to specify a service-oriented framework for device-level infrastructures, where system intelligence is achieved by intelligent physical agents embedded in smart devices.

In particular the project set up the following sub-objectives:

- **Development of a comprehensive device-level Service Oriented Architecture (SOA) infrastructure** based on the Devices Profile for Web Services (DPWS) – for encapsulating intelligence and sensing or actuating skills as services, as well as to specify associated frameworks for management and orchestration of device-level services.

  - **Definition of a methodology for describing services** with semantic mark-up that can be interpreted and processed by agents (Semantic Web Services), for the discovery, selection and composition of resources.

  - **Specification of a framework for service-enabled intelligent physical agents**.

  - **Specification of new wireless communication protocols** that provide the required reliability, safety, security and real-time parameters for embedded devices.

  - **Specification of middleware that encapsulates both the mechanisms to offer specific Quality of Service (QoS) provisions and the underlying wireless technologies**. It is the innovative middleware that has a key role to play in SOCRADES, in particular to:

    - enable the automated description, simulation, composition, testing, and verification of Web Services for embedded systems relevant to the application domains studied;

    - functionally bridge the gap between application programs and the lower-level hardware and software infrastructure in order to co-ordinate how parts of applications are connected and how they interoperate;

    - enable and simplify the integration of components developed by multiple technology suppliers;

    - provide a common reusable accessibility for functionality and patterns that formerly were placed directly in applications but that in actuality are application independent and need not be developed separately for each new application.

- **Addressing the challenges of networked control** over a wireless link and to incorporate the functionality into service-oriented architecture.

In view of their expanding business and marketing strategies, the project anticipates achieving groundbreaking future applications, in particular process automation and advanced control, based on seamless integration of wired and wireless networks combined with a universal communications infrastructure.

The use of the SOA paradigm at the device level enables the adoption of a unifying technology for all levels of the enterprise, from sensors and actuators up to enterprise business processes. This will lead to information being available “on demand” and allow business-level applications to use high-level information for such purposes as diagnostics, traceability and performance indicators – resulting in increased overall equipment effectiveness and business agility.